KamLAND 4π control system

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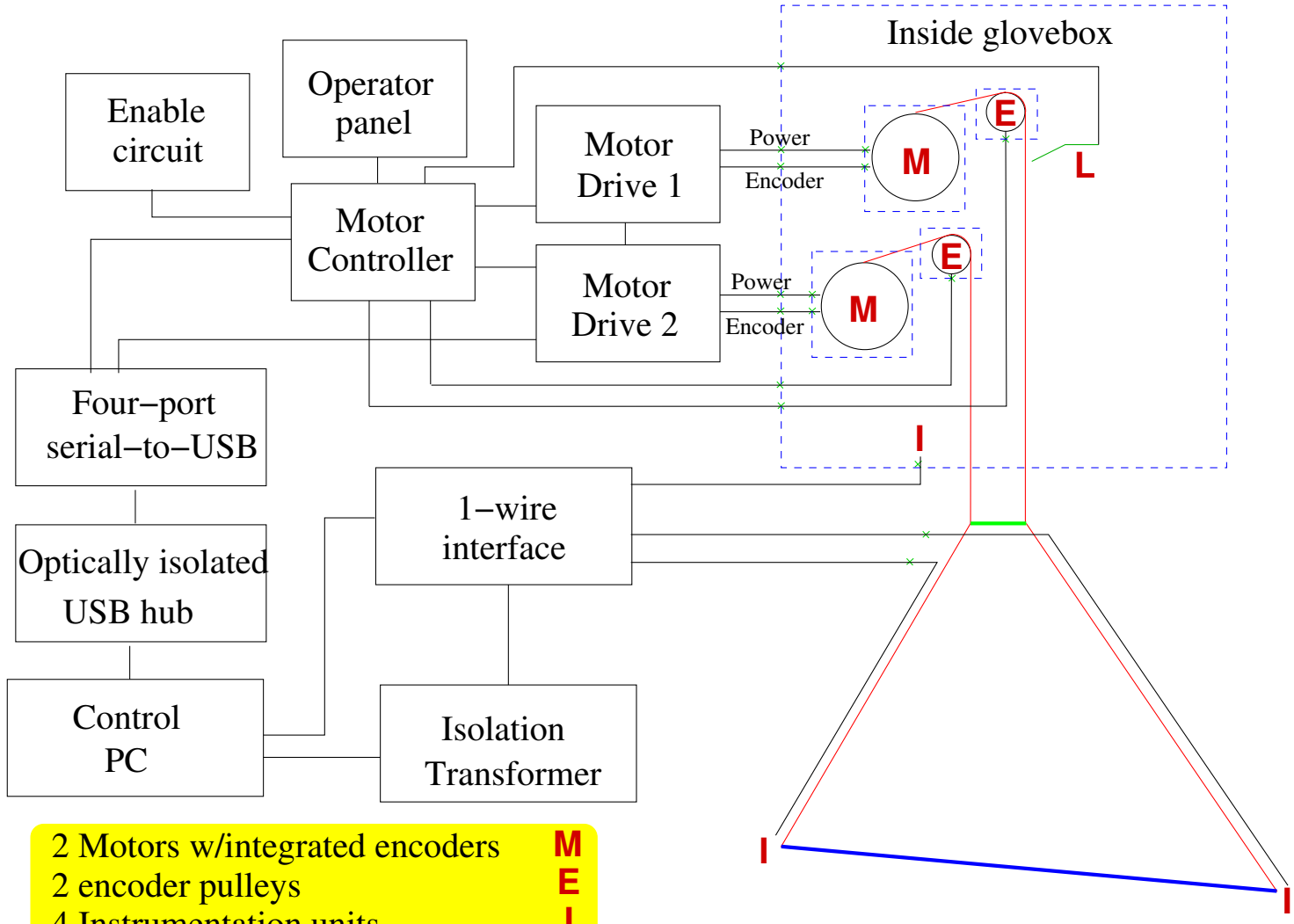
- Successful demonstration yesterday! ...may make this talk partially redundant.
- The electrons in this talk are $\sim$90% recycled.

Multiple layers of protection

...against mistakes that might damage the detector:

1. Written deployment protocol.
2. Operator – required to move in small steps where necessary.
3. Pre-verification of commanded motion.
4. Continuous cross-checks between various position measurements.
5. Immediate stop if measured position goes outside allowed region.

Control hardware



2 Motors w/integrated encoders **M**
2 encoder pulleys **E**
4 Instrumentation units **I**
1 Limit switch **L**

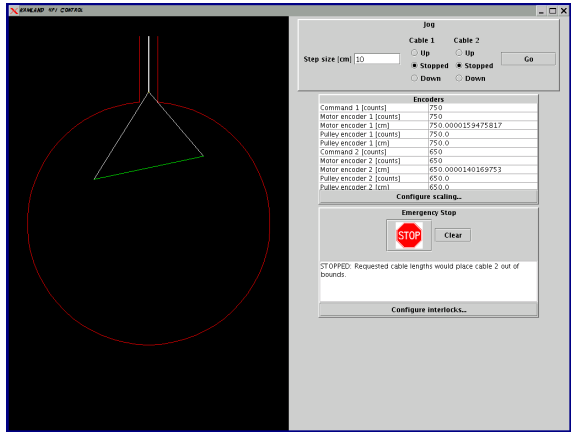
× = feedthrough required

Control hardware

Control software

Display software is more complex and failure-prone, so it is separated from the control software:

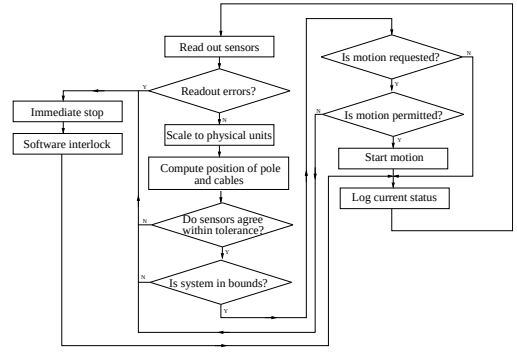
Display program



Parameters

(Java RMI)

Control program

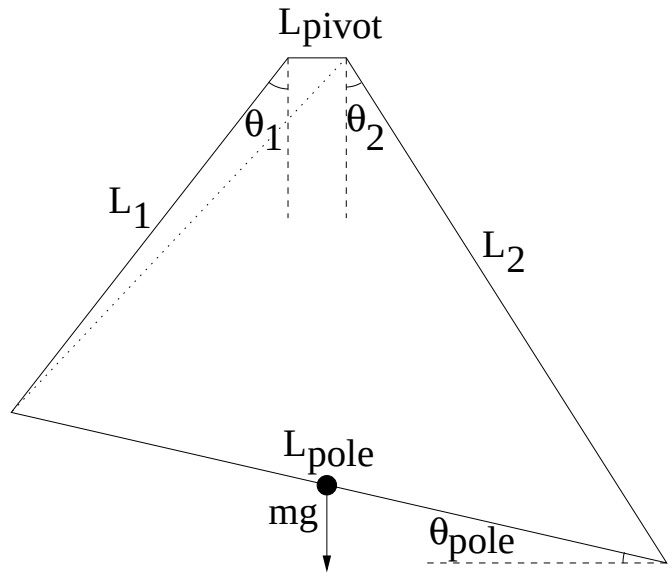


- If display program crashes, there is no effect on control program.
- If control program crashes, current motion is safe: each step is pre-approved before the motion command is issued. Also, timeout will occur.
- Either program can simply be restarted if necessary.

Stages of deployment

- During assembly of pole: use external manual controller (no constraints).
- Tare procedure with top segment held in pin block.
- During calibration, until pole withdrawal begins, all constraints are enforced:
  - All position measurements in agreement:
    - Primary: cable lengths from encoder pulley
    - Cable lengths from motor encoder
    - Instrumentation unit pressure sensors
    - Instrumentation unit accelerometers (tilt sensors)
  - Physics model indicates all components of system in bounds.
    - Allowed sphere, allowed cylinder
  - Slack in lower cable does not exceed specified value.
  - Each step must be OK even if one motor fails ($\sim$ 10 cm steps in critical region).
- During pole disassembly, shift back to manual controller.

Geometry and physics



- Except for one angle, dynamics of system are determined entirely by geometry.
- Numerical minimization of gravitational potential energy as θ_1 is varied (buoyant forces, weight of cables, etc. could be included easily).
- Currently, width of pivot block is neglected (numerical stability issue?).

Remaining tasks (shown in Gatlinburg)

- Integrate instrumentation units: add cross-checks between cable length and accelerometers/pressure sensors.
  - Currently solving electrical problems. (✓)
- Retension cables and recalibrate motor vs. pulley encoders. (✓, but need to do it again!)
- Re-enable the cross-checks that have been disabled for testing of partial system. ✓
- Repeat survey measurements.
- Insert real detector geometry.
- Provide easier access to history information (partially done: logging to database as well as text file).